

# Microbial Adhesion in Hollow Fiber Membrane Bioreactors for Wastewater Processing

Completed Technology Project (2014 - 2015)



## Project Introduction

This work examined novel modification techniques for polydimethylsiloxane (PDMS) fibers in order to promote microbial adhesion for use in Membrane Aerated Bioactors (MABRs); treatments were selected based on literature evidence demonstrating enhanced microbial adhesion. Treatments were down-selected in a series of initial adhesion and prolonged growth experiments for treatment of a wastewater similar to that seen on the International Space Station (ISS) including urine, humidity condensate water, hygiene wastewater, and laundry wastewater. By promoting increased microbial attachment to these PDMS fibers, the project team hopes to decrease the start up time for MABRs for application as a safe, reliable pre-treatment for wastewater treatment for ISS and future long-duration missions.

A key challenge in the use of membrane aerated bioreactors (MABRs) for wastewater remediation is the development and maintenance of a vigorous biofilm on the membrane surface. To achieve a robust and stable MABR, biofilm development must be rapid and structurally compatible with the application both in terms of thickness and resistance to shearing. The vast majority of studies examining biofilm structure and development focus on preventing rather than enhancing establishment, primarily to address medical and industrial concerns where biofilm development is a detriment. Only in recent years have studies examining techniques to promote biofilm attachment surfaced for use of such technology in wastewater treatment facilities. Most alterations made to membrane surfaces for improving bacterial adhesion involve chemical alterations of the polymer surface; i.e., surface modification based on adding various chemical functional groups to the fiber surface. Even a cursory review of the available literature quickly reveals a paucity of information on the alteration of polydimethylsiloxane (PDMS) fibers for improved bacterial adhesion. The majority of membrane modification studies to date have focused on polyethylene (PE) and polypropylene (PP) fibers.

The focus of this work is to examine novel modification techniques for PDMS; treatments were selected based on literature evidence demonstrating enhanced microbial adhesion. A systematic approach was used to down-select treatments for subsequent studies including initial adhesion capacity and long-term biofilm growth capability. Physical characterization of the treated surfaces including contact angle and surface charge determination were examined in order to down-select treatments for initial adhesion studies. A further down-selection from the initial adhesion studies served to provide promising samples for an advanced biofilm growth experiment with a focus on nitrifying bacteria. Treatments experiencing the highest levels of initial adhesion were tested in FAME modules (Fiber Attachment Module Experiment), developed at Kennedy Space Center, using a minimal salt feed and KSC inoculum source for enhanced nitrification performance. Further experimentation included top-performing fiber treatments from the minimal salt feed studies against a wastewater stream similar to that seen on the



ESC Project Team and NASA Interns contributing to project.

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International Space Station (ISS) including urine, humidity condensate water, hygiene wastewater, and laundry wastewater.

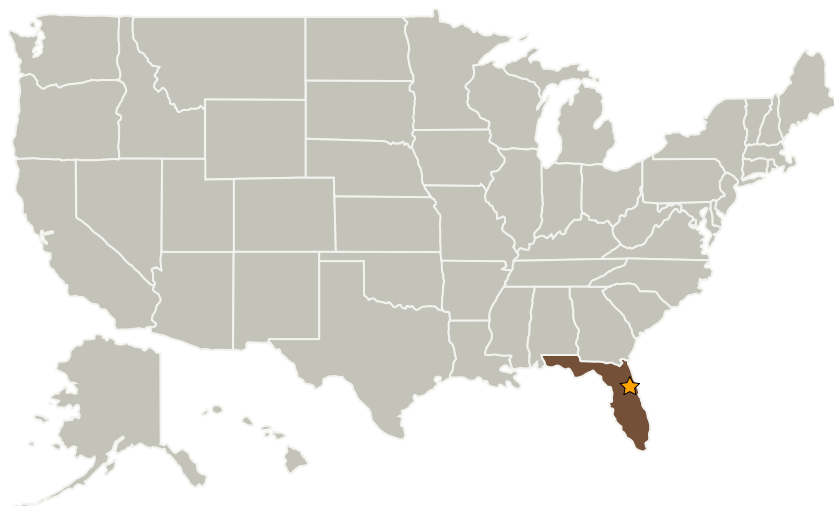
By promoting increased microbial attachment to these PDMS fibers, the project team hopes to decrease the start up time for MABRs for application as a safe, reliable pre-treatment for wastewater treatment for ISS and future long-duration missions. Future work in this field would utilize the top treatment determined from this study in a high-fidelity sub-scale MABR system to monitor the time to steady-state operation and biofilm growth compared to non-treated fibers.

## Anticipated Benefits

The success of this project would lead to increasing the technical readiness level (TRL) of bioreactor systems for use as a pre-treatment for ISS or future long duration mission wastewater. Integration of biological systems into water processing systems would allow for elimination of hazardous, caustic chemicals currently used to stabilize urine and treat the waste stream. Currently, scale-up studies continue with traditional, non-treated fibers to integrate MABRs into the Alternative Water Processor (AWP). The technology under development here could further advance the success of this larger project.

Beyond application for NASA-funded projects, this work has application for use within agencies such as the EPA, where similar wastewater streams and reactor systems are currently being studied; further, biological systems in this configuration could be used to also treat hazardous waste streams.

## Primary U.S. Work Locations and Key Partners



## Organizational Responsibility

### Responsible Mission Directorate:

Mission Support Directorate (MSD)

### Lead Center / Facility:

Kennedy Space Center (KSC)

### Responsible Program:

Center Independent Research & Development: KSC IRAD

## Project Management

### Program Manager:

Barbara L Brown

### Project Manager:

Nancy P Zeitlin

### Principal Investigators:

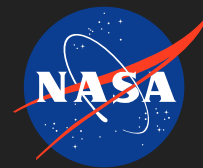
Janelle L Coutts  
Raymond M Wheeler

### Co-Investigators:

James P Bond  
Joerg Lahann

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Organizations Performing Work	Role	Type	Location
★ Kennedy Space Center(KSC)	Lead Organization	NASA Center	Kennedy Space Center, Florida
PVA Tepla America	Supporting Organization	Industry	
University of Michigan-Ann Arbor	Supporting Organization	Academia	Ann Arbor, Michigan

## Primary U.S. Work Locations

Florida

## Images



### ESC Project Team

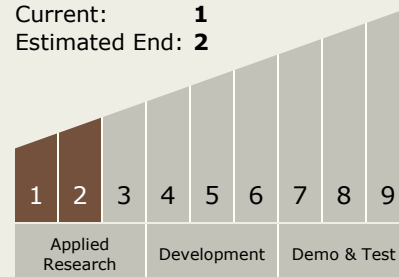
ESC Project Team and NASA Interns contributing to project.  
(<https://techport.nasa.gov/image/18377>)

### FAME Fiber Comparison

A) Control vs. B) Treated Fibers showing significantly more biofilm adhesion after 21 days.  
(<https://techport.nasa.gov/image/18375>)

## Technology Maturity (TRL)

Start: **1**  
Current: **1**  
Estimated End: **2**



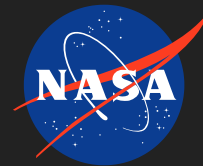
## Technology Areas

### Primary:

- TX06 Human Health, Life Support, and Habitation Systems
  - TX06.1 Environmental Control & Life Support Systems (ECLSS) and Habitation Systems
    - TX06.1.2 Water Recovery and Management

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## FAME work

Summer Intern, Kristian Staerk,  
harvesting fibers from FAME after  
21-day experiment  
(<https://techport.nasa.gov/image/18376>)

## Links

KSC-13990  
(no url provided)